~~CONFIDENTIAL~~ [redacted]

EXCLUDED FROM AUTOMATIC REGRADING; DOD DIR 5200.10 DOES NOT APPLY

POR-1810
(WT-1810)

This document consists of 36 pages

No. of 405 copies, Series A

DEPARTMENT OF DEFENSE
U.S. ATOMIC ENERGY COMMISSION

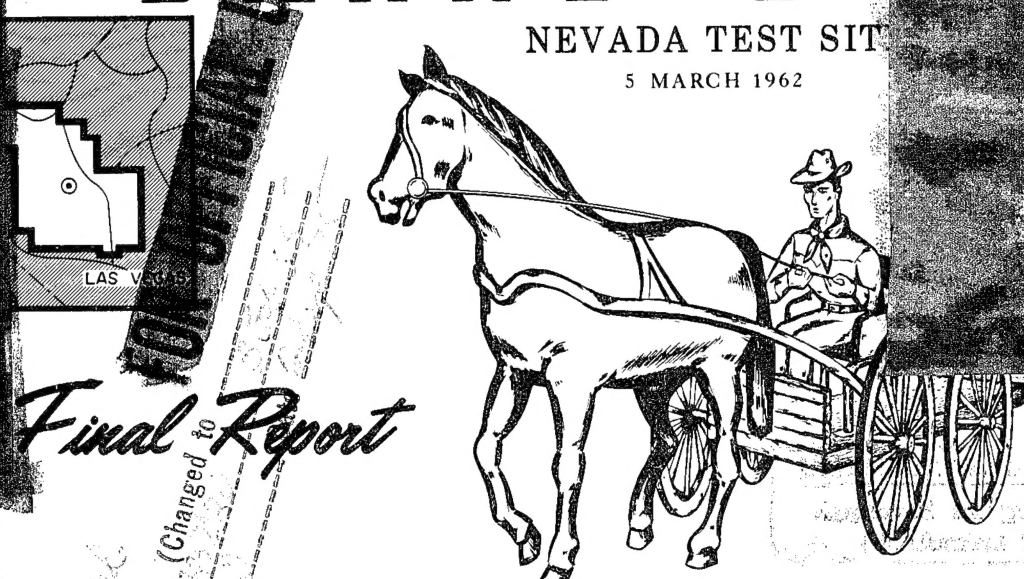
[redacted]

Project

DANNY BOY

NEVADA TEST SIT [redacted]

5 MARCH 1962



FOR OFFICIAL USE ONLY

Final Report

CLOSE-IN AIR BLAST FROM A NUCLEAR DETONATION IN BASALT

L. J. Vortman

SANDIA CORPORATION

FORMERLY RESTRICTED DATA

Classification (Cancelled) (Changed to)
By Authority of

Classification (Cancelled) (Changed to UNCLASSIFIED)
By Authority of

By

DISTRIBUTION STATEMENT A APPLIES PER NTPR REVIEW.

DATE 6/22/95

DASA

Inquiries relative to this report may be made to

Chief, Defense Atomic Support Agency
Washington 25, D. C.

When no longer required, this document may be destroyed in accordance with applicable security regulations.

DO NOT RETURN THIS DOCUMENT

USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

Defense Nuclear Agency
6801 Telegraph Road
Alexandria, Virginia 22310-3398

SSTL

28 June 1995

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
ATTN: OCD/Mr. Bill Bush

SUBJECT: Inclusion of POR-1810 Into DTIC System.

The Defense Nuclear Agency shows no record of the subject report ever being in the DTIC system.

Therefore, it is requested that the report be entered. The **report (POR-1810) is UNCLASSIFIED, approved for public release.**

This office would appreciate notification of your assigned accession number.

FOR THE DIRECTOR:

Sincerely,

Josie Wood

JOSEPHINE B. WOOD
Chief, Technical Support

Enclosure:
A/S

[redacted]

PROJECT DANNY BOY

[redacted]

POR-1810
(WT-1810)

PROJECT 1.1b

CLOSE-IN AIR BLAST FROM A NUCLEAR DETONATION IN BASALT

L. J. VORTMAN

Sandia Corporation
Albuquerque, New Mexico

June 1962

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

ABSTRACT

Close-in air blast from the Danny Boy event resulted almost entirely from the ground-shock-induced air blast. Little pressure resulted from venting gases. Consequently, measured pressures were only one-third to one-fourth of those predicted. Ground-shock-induced pressures from the nuclear charge were found to attenuate less rapidly than those from chemical explosives.

[redacted]

[redacted]

[redacted]

ACKNOWLEDGEMENTS

The author wishes to thank Mr. D. P. LeFevre, Ballistic Research Laboratories, for making the blast measurements and reducing the data for Project Danny Boy and Mr. F. Shoemaker for coordinating the project in the field.

CONTENTS

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

The objective of the air blast measurement program was to determine the overpressure-time-distance relationship at ground level along one blast line for the purpose of determining the extent of close-in blast suppression. This experiment extends blast observations from charges buried in basalt to 430 tons, a yield larger by a factor of 20 than yields of Project Buckboard. The new data permit some indication of the extent to which differences in close-in blast can be attributed to differences in the type of explosive used (nuclear or chemical explosive).

1.2 BACKGROUND

Close-in air blast along the ground surface has been measured on underground detonations from high explosives in Nevada Test Site desert alluvium using high-explosive charges of 256 (References 1, 2, and 3), 2,560 (Reference 1), 40,000 (References 1 and 4), and 1,000,000 (Reference 5) pounds. It has also been observed on a surface nuclear detonation (References 6 and 7) and on two relatively shallow nuclear detonations (References 6, 7, and 8) in the same medium. On Project Buckboard (Reference 9) blast overpressures were measured along the ground from three 40,000-pound detonations at three different burst depths in basalt. The Buckboard experiments led to the conclusion that no difference in the suppression of peak overpressure is attributable to the harder medium; that is, with high explosives, suppression of peak overpressure is essentially the same in alluvium and basalt.

A typical overpressure waveform from an underground high-explosive detonation shows a ground-shock-induced pressure pulse (often referred to as the "front porch") followed by the main portion of the blast wave

generated by the venting of the explosion gases (Figure 1.1a). The waveforms from Project Danny Boy (Figure 1.1b) are explained later.

1.3 INSTRUMENTATION

1.3.1 Gage Locations

Gages were located along an approximately SE radius at radial distances along the ground at 200, 265, 350, 470, 630, 840, 1120, 3100, and 8500 feet. Typical gage installations are shown in Figure 1.2. Figure 1.3 shows the completed gage installation with the cleared area immediately around the gage. This photograph was taken looking toward surface zero.

1.3.2 Gage Types

Measurements were made using Ballistic Research Laboratories self-recording pressure gages (Figure 1.4). In these gages, a battery-operated motor drives a turntable carrying either an aluminized glass disc or a stainless steel disc. A pressure sensitive diaphragm, connected directly to a scribe, permits the pressure record to be inscribed on the disc as the turntable rotates. The gage motor is started by a timing signal at -1 second. Standard pressure-time gages (PT's) were used at Stations 1 through 7, and very low pressure gages (VLP's) were used at Stations 6 through 9). Both types of gages were installed at Stations 6 and 7.

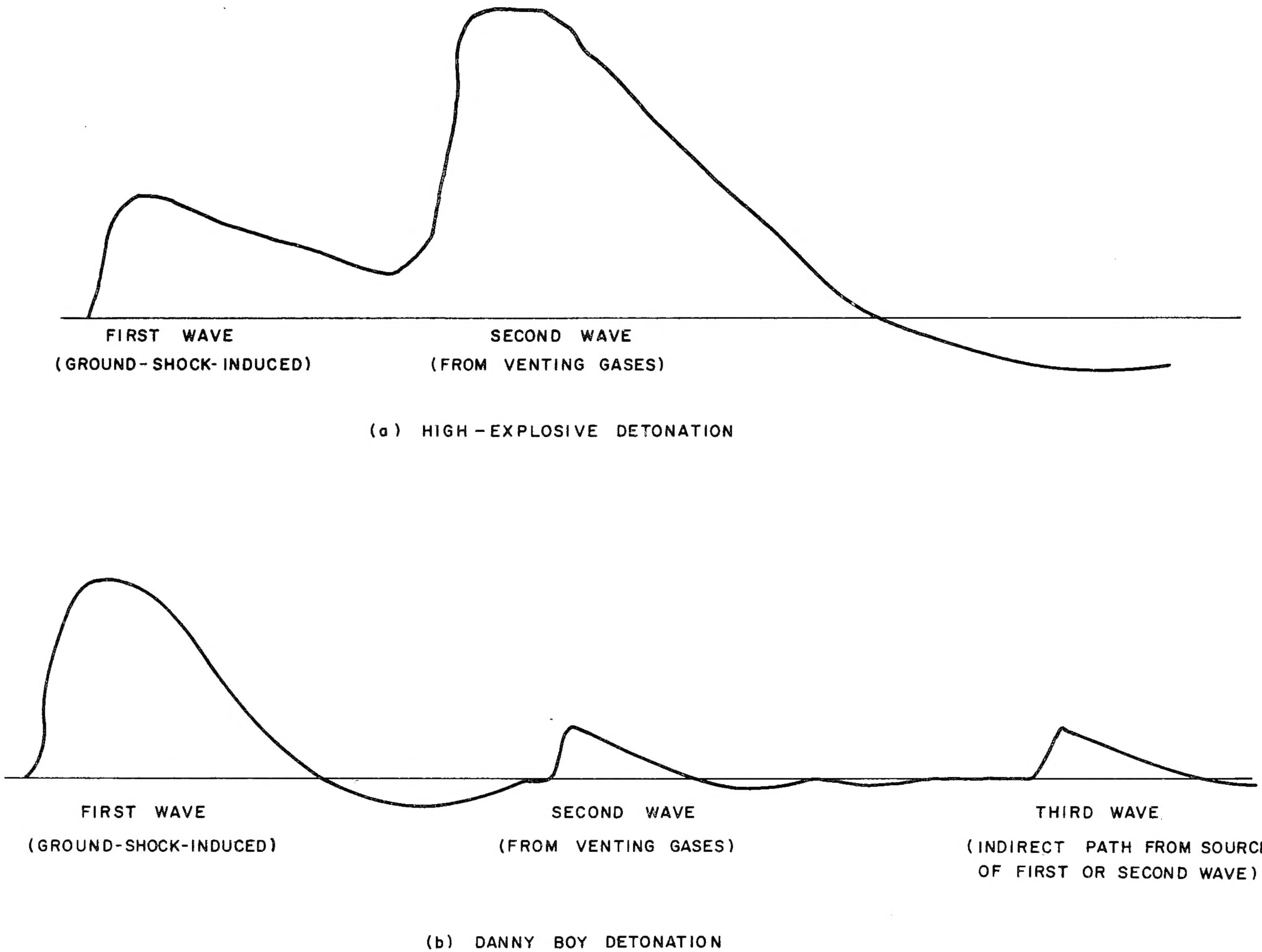


Figure 1.1 Typical Waveforms from Buried HE and Nuclear Detonation

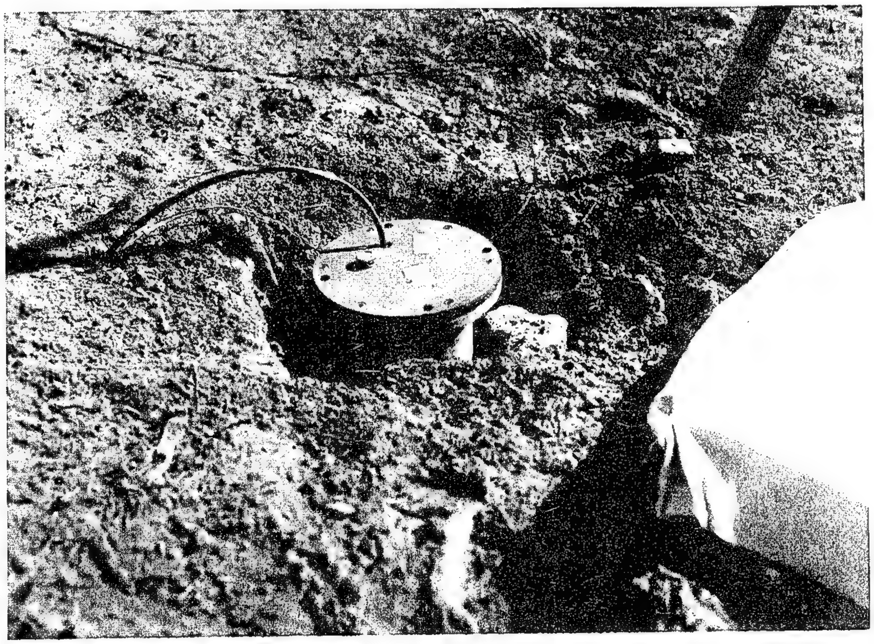


Figure 1.2 Typical Gage Installation

Figure 1.3 Cleared Area Around Gage Installation

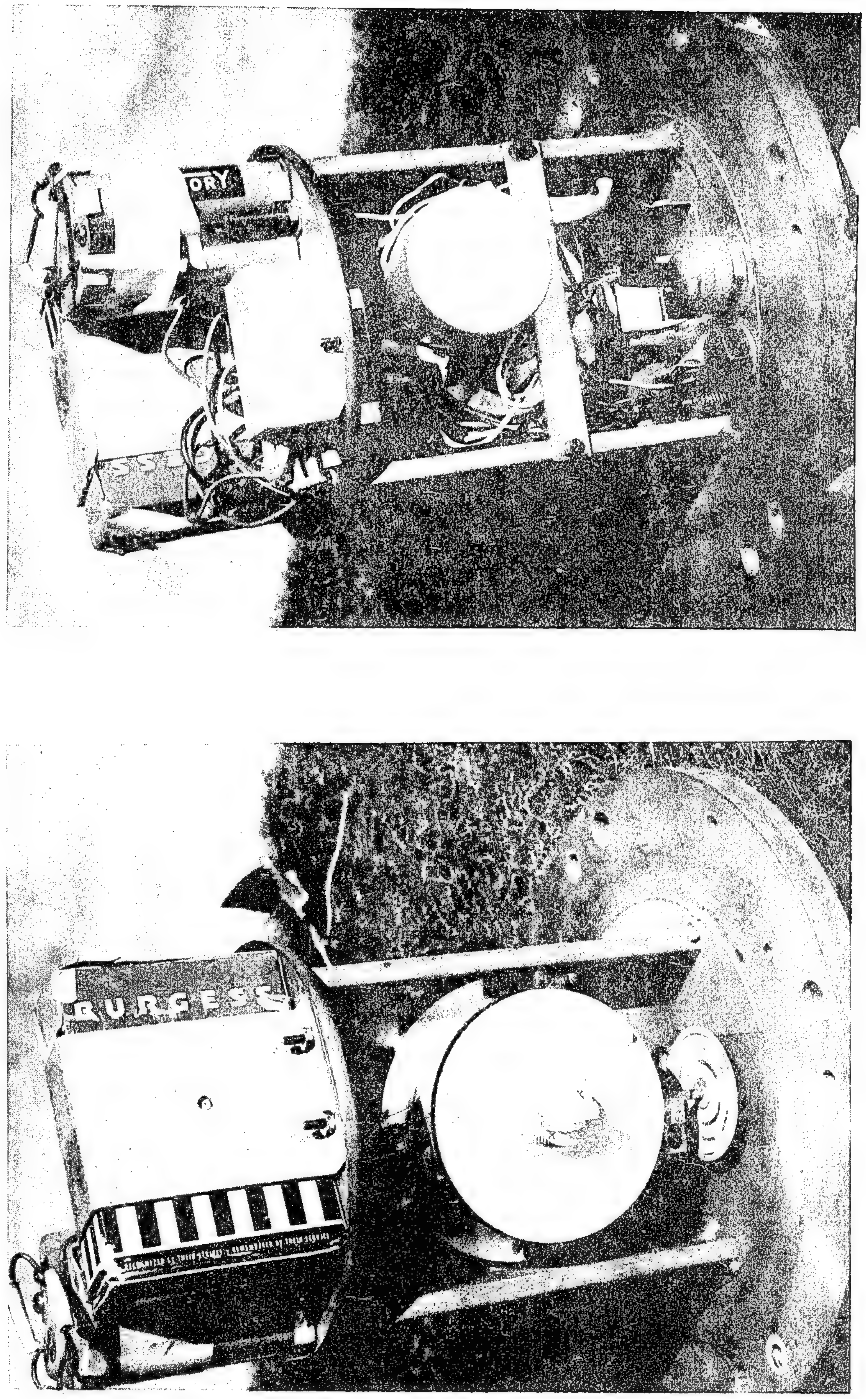


Figure 1.4 Self-Recording Pressure-Time Gage

CHAPTER 2

TEST RESULTS

2.1 SUMMARY OF RESULTS

Table 2.1 summarizes the results of the pressure measurements. Because peak pressures only were obtained at Stations 5, 6B, 7B, and 8, records of pressure-time are not reproduced. Pressure records from the remaining seven gages are shown in Figures 2.1 through 2.4. Time in the figures is time from the arrival of the signal shown. The pressure wave illustrated is the first wave in all cases except at the 3100-foot station (Station 8), where the wave shown, as explained later, is from another source.

2.2 PEAK OVERPRESSURE

Figure 2.5 shows peak overpressures as a function of ground range. Also shown is the curve predicted before the shot for a slightly larger yield and a comparatively deeper burst depth; set ranges of the gages were based upon this curve. As indicated by the figure, all pressure records obtained were one-third to one-half of the set range.

2.3 POSITIVE PHASE

The positive-phase impulse of the pressure records is shown in Figure 2.6. The duration of the positive phase as a function of ground range is given in Figure 2.7. As is usual in pressure measurements, the scatter in positive-phase duration data is considerably greater than that in either peak overpressure or positive-phase impulse.

2.4 ARRIVAL TIMES

Arrival times are plotted in Figure 2.8.

TABLE 2.1 SUMMARY OF RESULTS

Station	Ground range (feet)	Type of gage	Capsule range (psi)	Peak pressure (psi)	Arrival time (sec)	Positive-phase duration (sec)	Positive-phase impulse (psi-msec)
1	200	PT	1/2	.255	-	.276	48.3
2	265	PT	1/2	.16	.510	.250	23.08
				.04	1.48	.685	
3	350	PT	1/2	.11	.815	.365	21.36
				.02	1.83	.410	
4	470	PT	1/2	.12	1.075	.505	19.86
				.04	1.485	.08	
				.03	2.38	.70	
5	630	PT	1/2	.075	PEAK	ONLY	
6A	840	PT	1/2	.045	1.070	.145	3.52
6B	840	VLP	1/4	.080	PEAK	ONLY	
7A	1120	PT	1/2	.055	1.385	.345	10.47
7B	1120	VLP	1/4	.070	PEAK	ONLY	
8	3100	VLP	1/4	.027	3.64		
				.065	11.25	.125	2.72
9	8500	VLP	1/4	.060	PEAK	ONLY	

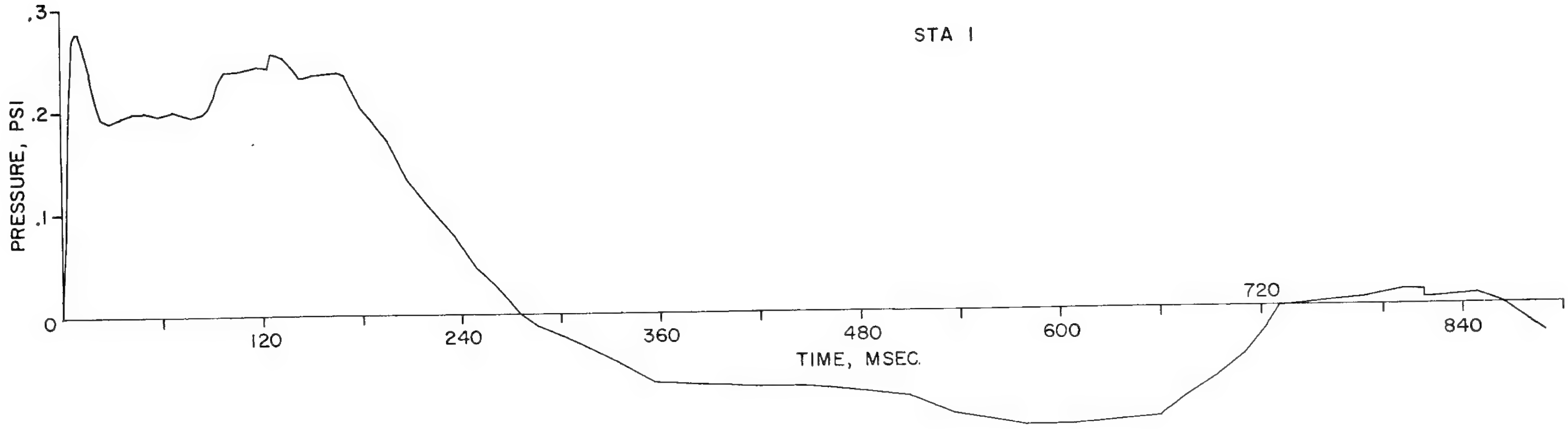


Figure 2.1 Pressure Records

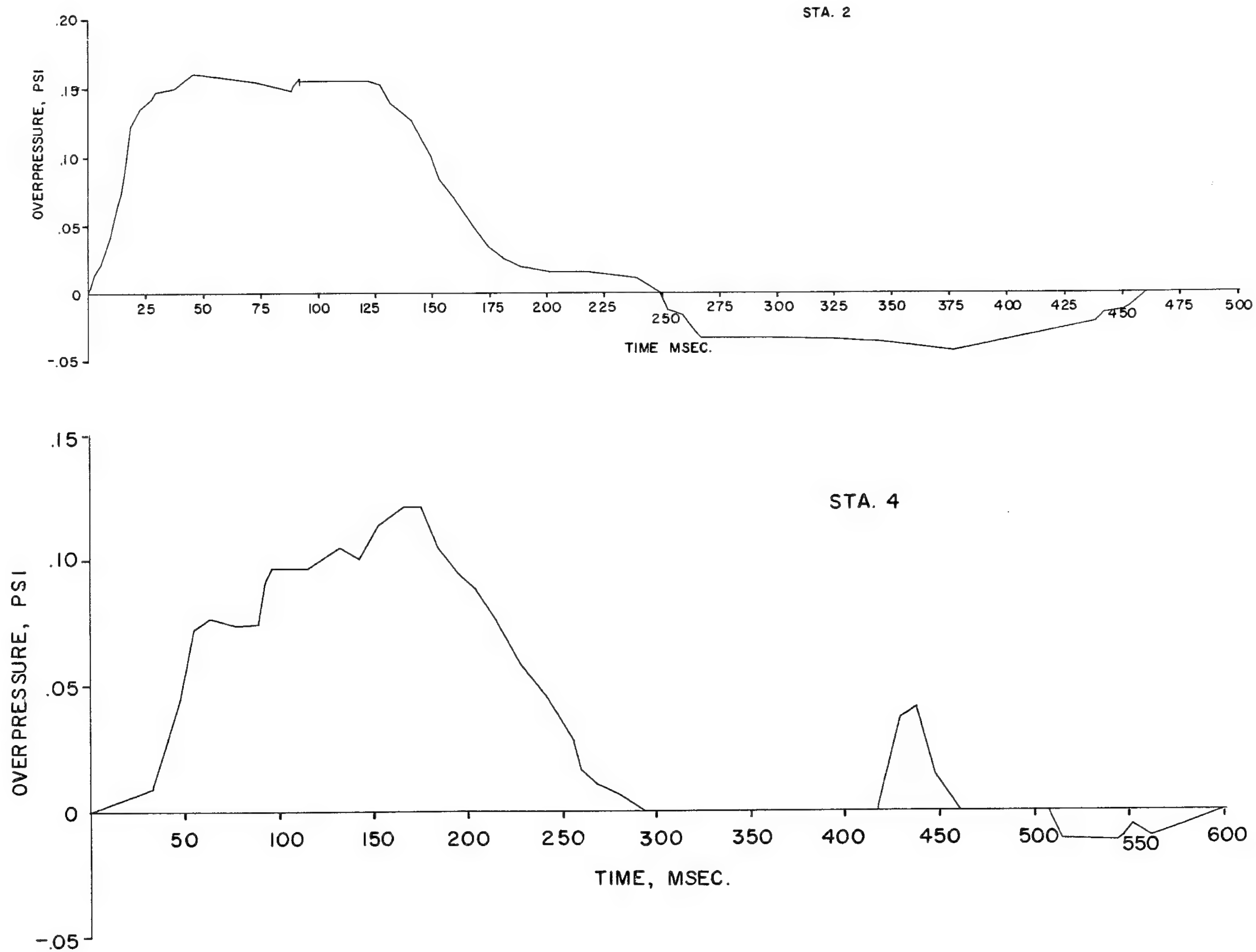


Figure 2.2 Pressure Records

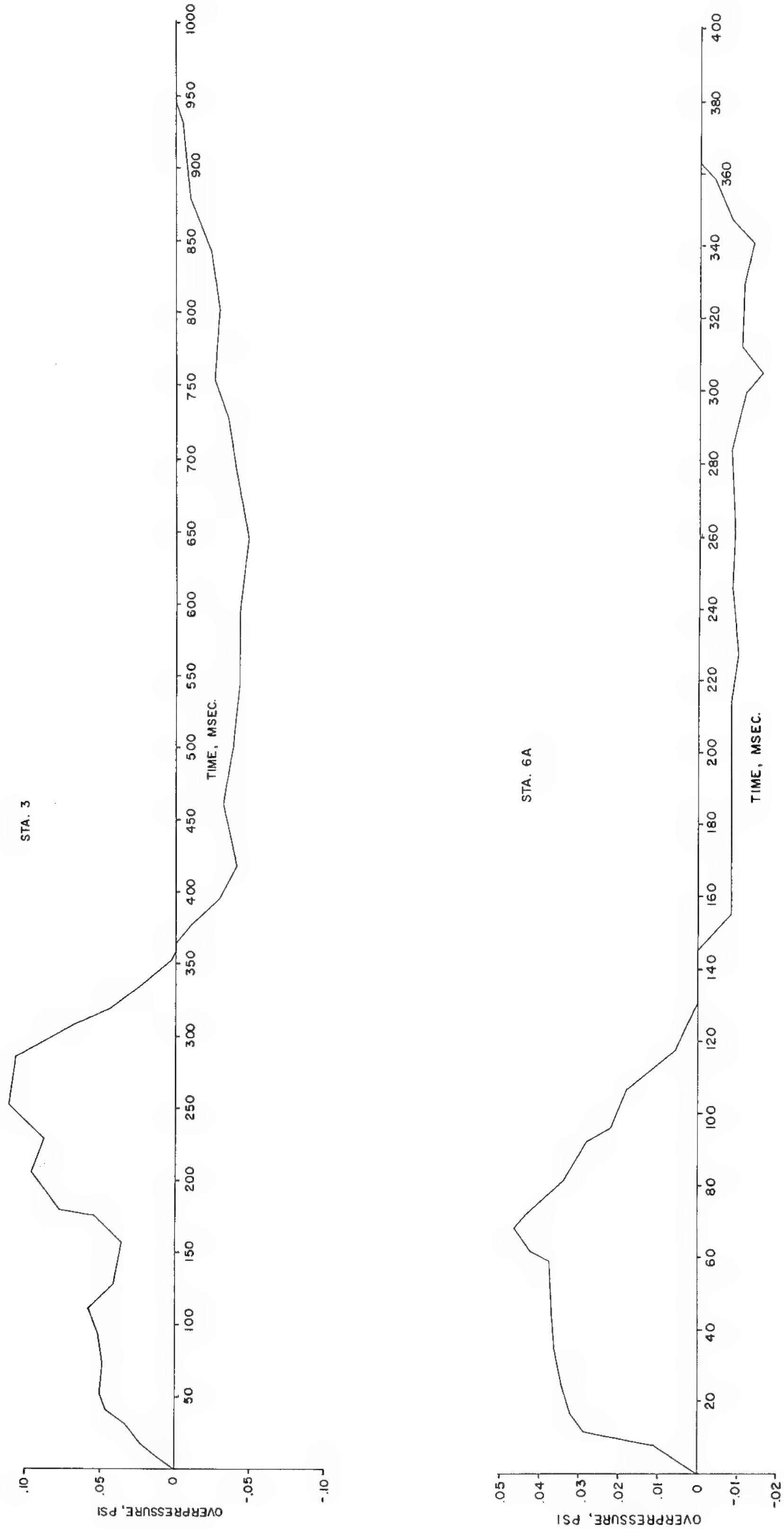


Figure 2.3 Pressure Records

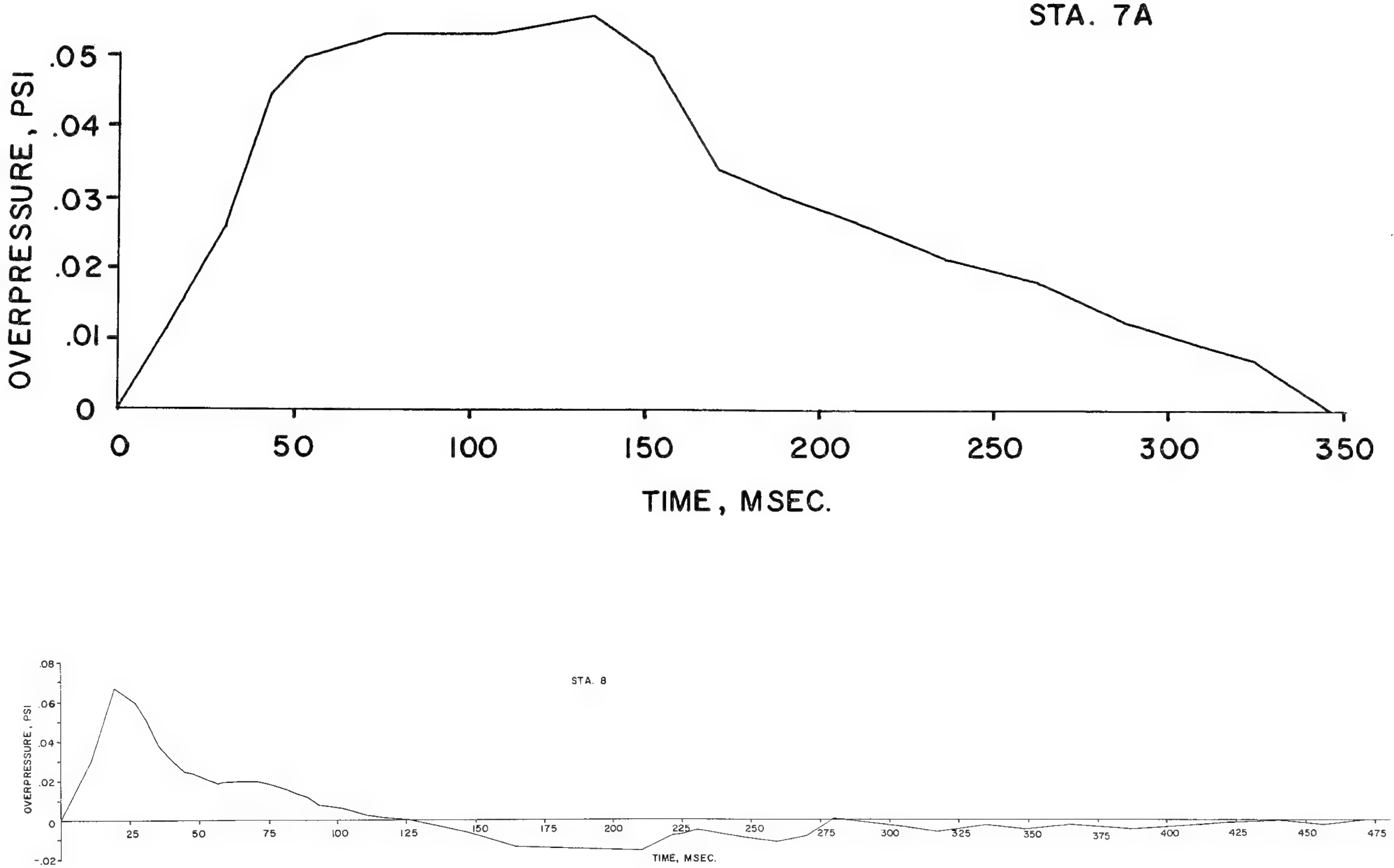


Figure 2.4 Pressure Records

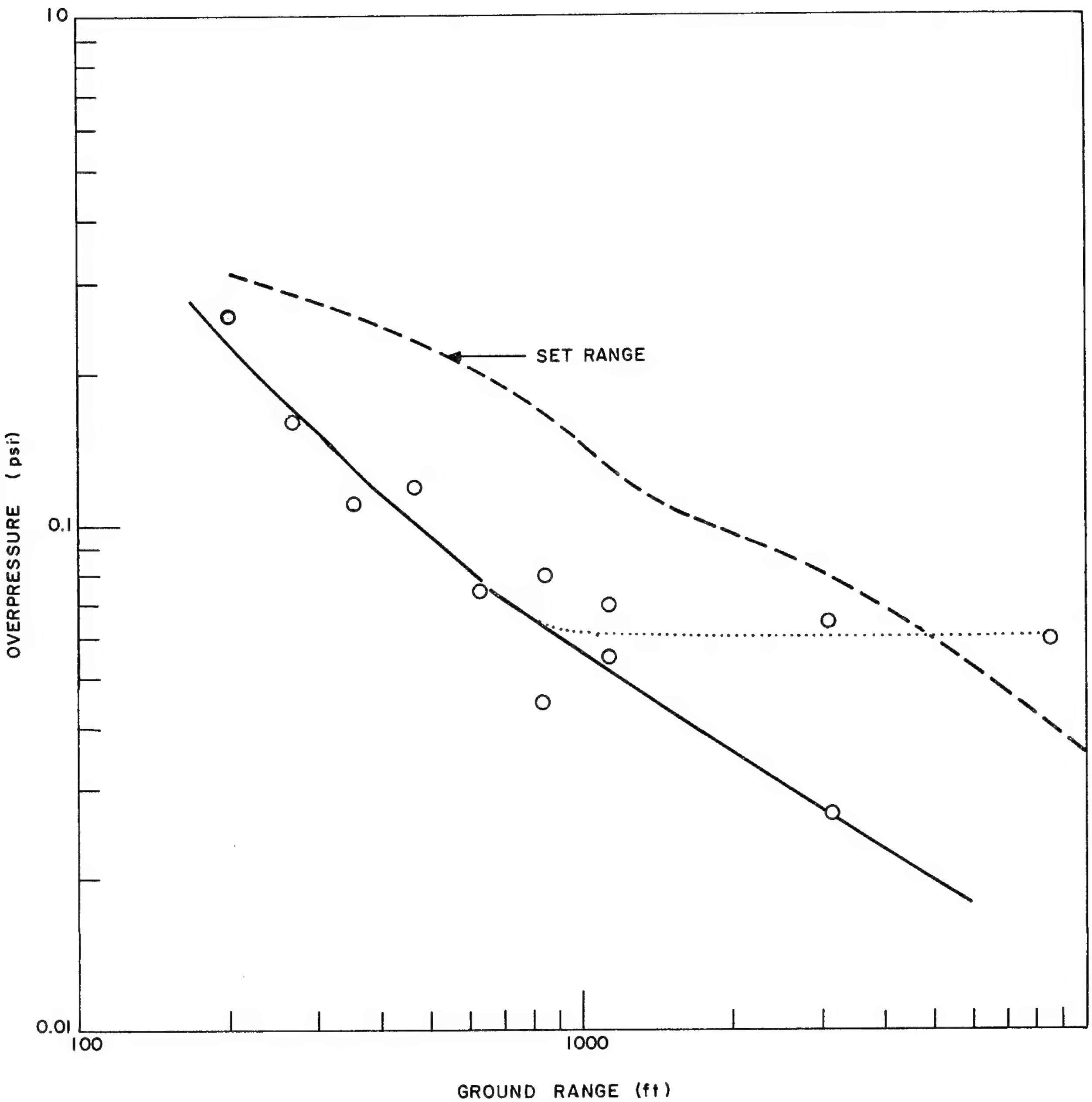


Figure 2.5 Maximum Overpressure versus Ground Range

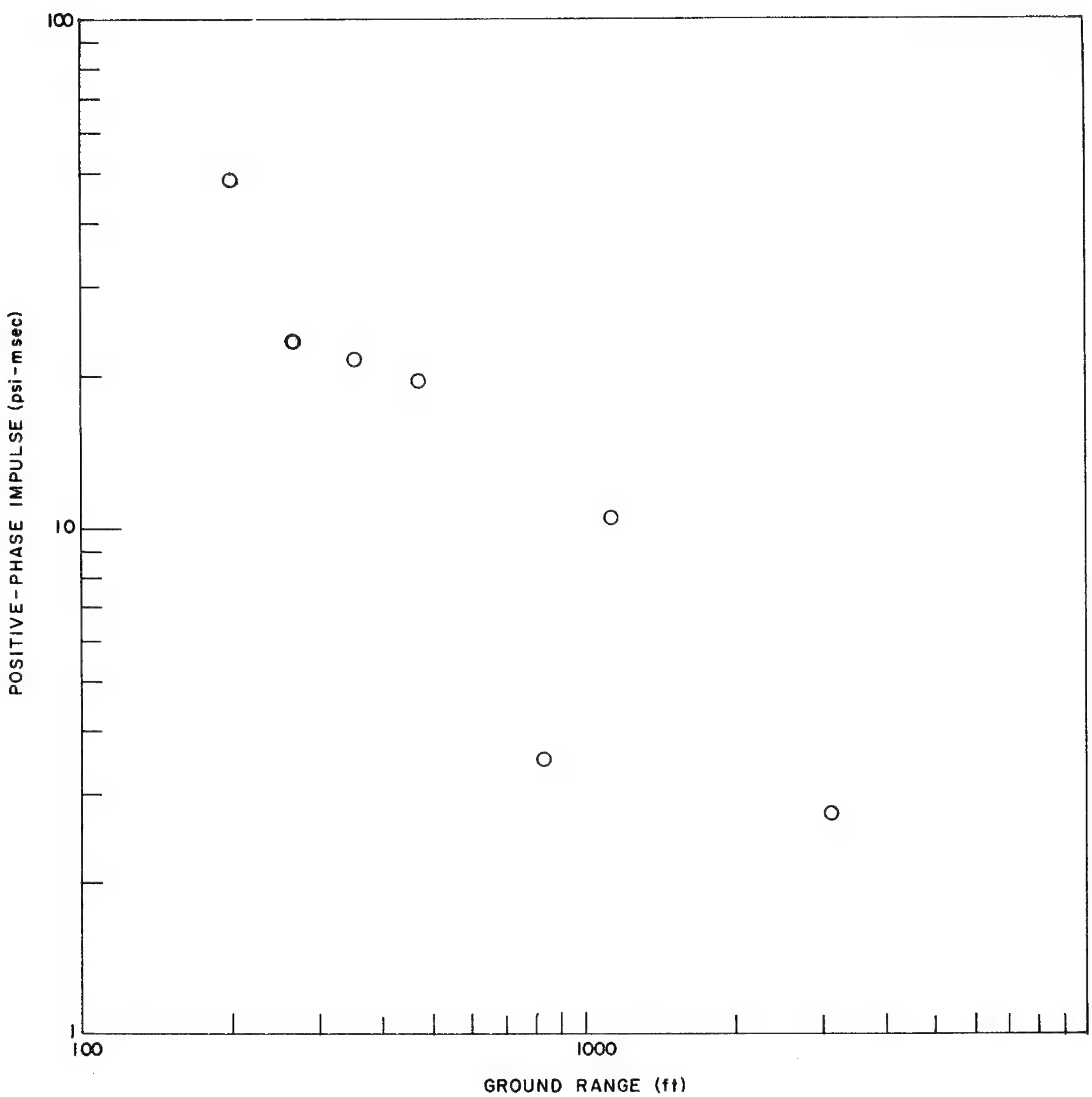


Figure 2.6 Positive Impulse versus Ground Range

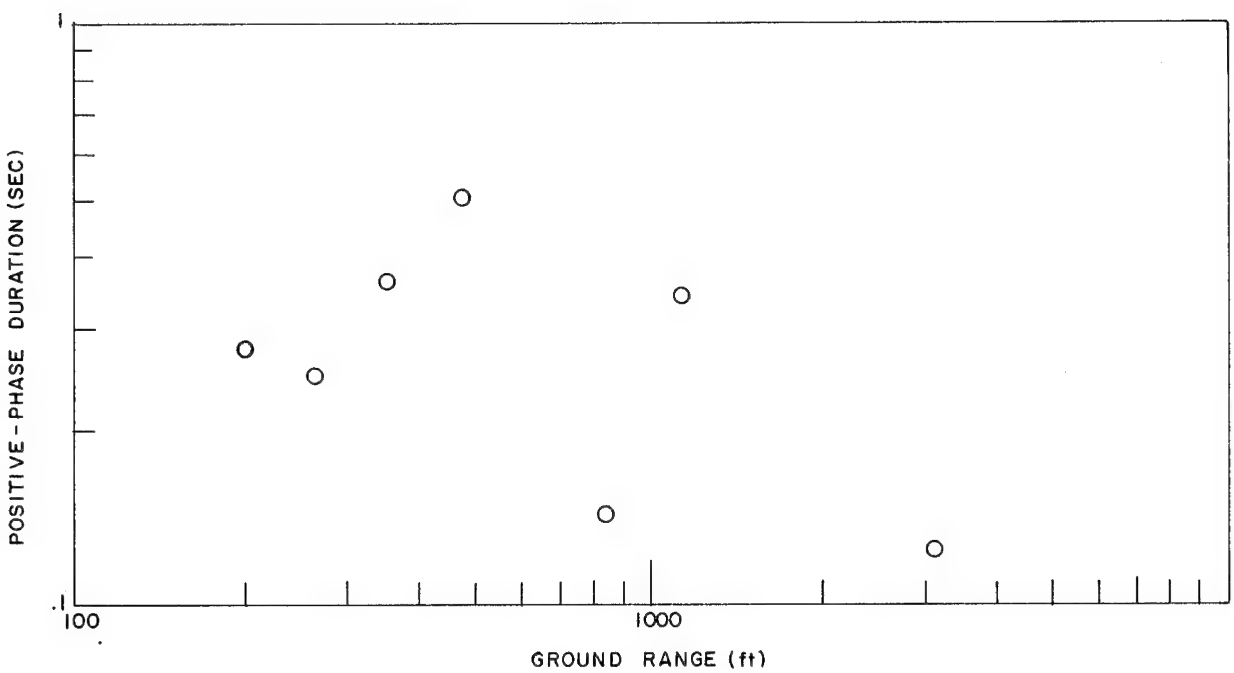


Figure 2.7 Positive Phase Duration versus Ground Range

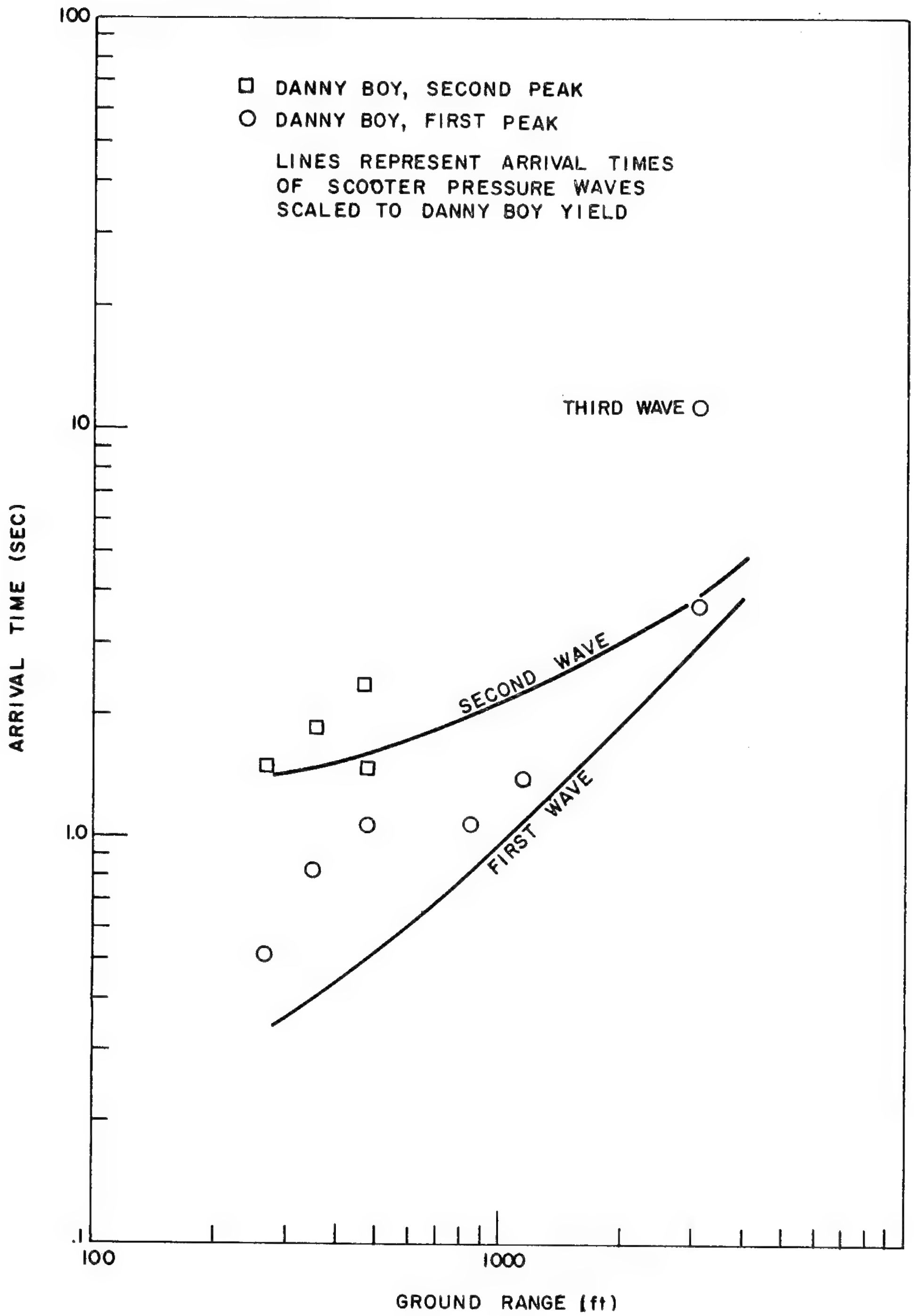


Figure 2.8 Arrival Time versus Ground Range

CHAPTER 3

DISCUSSION

3.1 WAVE SHAPE

The most unusual thing about the waveforms from the Danny Boy detonation is that upon first examination they showed only a single pressure pulse, that shown in Figures 2.1 to 2.4. This is in contrast to waveforms from high-explosive detonations in basalt and desert alluvium (Buckboard Shot 12 and Scooter) at an only slightly greater burst depth; these have shown two distinct pulses, the second one dominant.

Initial plotting of the arrival times of these waves (Figure 2.8) only added to the confusion, since they fell between those of the first and second waves of Scooter scaled to the Danny Boy yield. In addition, the arrival time at 3100 feet (Station 8) was far too late to be directly associated with the waves whose arrivals were noted from the closer stations.

Careful scrutiny revealed barely discernable signals following the main signals at the four closest stations (Stations 1, 2, 3, and 4). Plots show (Figure 2.8) that these waves follow the preceding ones by about the same interval that the Scooter waves followed the first. This suggested that the main signals were ground-shock-induced waves, and that the very weak secondary waves were caused by venting gases. These latter waves were too much attenuated to be observed at Stations 6, 7, and 8.

Similarly, close examination of the record from Station 8 shows a very weak earlier wave whose amplitude was only 0.027 psi. Its arrival time was in agreement with arrivals of the dominant (first) wave at the other stations. This fact, together with the observation that the second wave had disappeared at even closer stations, leads to the conclusion that the weaker wave was the first or ground-shock-induced wave, that the second wave had disappeared, and that the third and dominant signal at Station 8 must have had a different origin. Since amplitudes at Stations 8 and 9 are nearly the same, the wave must have attenuated very slowly. The arrival of the third wave at Station 8

at 11.25 seconds and its amplitude justify its being attributed to a 2400-pound microbarograph calibration charge detonated 11,800 feet away at zero time. Obviously, the values from this wave cannot be considered further in relation to Project Danny Boy.

3.2 PEAK OVERPRESSURE

Peak overpressures of the main (first) wave as a function of ground range scaled to a 1-pound charge are shown in Figure 3.1. The relatively constant overpressure beyond 12 $ft/lb^{1/3}$ represents the third wave, attributed to the microbarograph calibration shot. Also shown in Figure 3.1 is a curve representing expected pressures from the second or gas-venting pulse based on high-explosive data at the same scaled burst depth. For this pulse, there was essentially no difference in peak overpressure from high explosives detonated in alluvium and basalt, and it was upon the combined data that the estimates of expected overpressures had been based. Since the arrival times (Figure 2.8) were bracketed by the arrival times of first and second pulses of Project Scooter scaled to Danny Boy yield, they could not be used without the later arrivals at the three closest stations to indicate conclusively whether the single pulse shown on the Danny Boy records represented a ground-shock-induced air shock or a gas-venting pulse.

An examination of Project Buckboard data shows that the first ("front porch") wave from Buckboard Shot 11 at a scaled burst depth of 0.75 $ft/lb^{1/3}$ is given by $p = 1.2\ r^{-.97}$, where r is the scaled ground range. For Buckboard Shot 12 at a scaled burst depth of 1.25 $ft/lb^{1/3}$, the relationship was $p = 0.9\ r^{-1.1}$*. Interpolation between these relationships gives a predicted "front porch" wave for Danny Boy of about $p = 0.95\ r^{-1.1}$. This relationship is shown in Figure 3.1. The close agreement of the measured data to this prediction is taken as final evidence that the dominant pulse measured is, in fact, the ground-shock-induced air shock. A best-fit pressure-distance relationship for the measured pressures is about $p = 0.32\ r^{-.70}$. Even with this spread between measured and predicted pressures, it is clear (1) that peak pressures from the nuclear shot are less than were predicted from high-explosive data and (2) that the pressure attenuates less rapidly from the nuclear detonation than it did from high-explosive detonations in the same medium and at comparable burst depth.

---

*Pressures in the first wave in alluvium are less; the corresponding relationship for Scooter being $p = 0.52\ r^{-1.1}$.

Peak overpressure values for the gas-venting pulse at the three closest stations are also shown in Figure 3.1. These signals are so small a part of set range that great precision cannot be obtained. They do show that the gas-venting pulse is only about one-third as large as the ground-shock-induced pulse. This is in contrast to high-explosive experience where the ground-shock-induced pulse at nearly the same scaled burst depth is about one-third of the gas-venting pulse.

All values from the gage at Station 6A are low, but a careful re-evaluation revealed no reason for modifying the numbers shown.

3.3 POSITIVE-PHASE IMPULSE

Although it is possible to define the peak overpressure associated with each portion of the blast wave, it is not worthwile to define their positive-phase impulses. This is because the amplitudes of all but the dominant wave of Danny Boy are so low (only a few mils on the original record) and such a small portion of set range that scatter in data is especially large. Also, comparisons with high-explosive data are difficult, because there the "front porch" typically runs into the dominant wave, making it impossible to define them separately. Therefore, it was to be expected that the values measured on Project Danny Boy, consisting only of impulse from the ground-shock-induced wave, would fall below the impulses predicted from high-explosive waves, which are made up of contributions from both the ground-shock-induced and gas-venting waves (Figure 3.2).

3.4 POSITIVE-PHASE DURATION

As in the case of the positive-phase impulse, only the positive-phase duration of the dominant wave of Danny Boy can be compared with the total positive-phase duration from high explosives, which includes both first and second waves. Danny Boy results and a comparison with total positive-phase duration from high-explosive tests scaled to 1 lb are shown in Figure 3.3.

3.5 EXPLOSIVE IMPLICATIONS

Close-in air blast from above-ground detonations is known with sufficient accuracy that estimates of explosive yield can be made from pressure-distance observations. Only slightly less accurate estimates can be made for

high-explosive detonations underground where the gas-venting pulse is dominant. For nuclear charges in basalt at deeper depths below ground, as evidenced by Danny Boy where the dominant pulse is ground-shock-induced, such estimates appear to have little meaning. Because the dominant wave from the nuclear detonation appears to attenuate less rapidly then the first wave from high-explosive detonations, estimates of Danny Boy yield vary with the ground distance of the peak pressure observations from 75 tons near the closest station to 325 tons at 1120 feet.

The very small gas-pressure pulse from the Danny Boy event may be attributed to the almost total lack of moisture in the basalt. More significant, second pulses may be expected from detonations in media with greater water content or in media (such as limestone) where chemical reactions can be expected to produce higher gas pressures. These measurements are useful in determining the relative importance of gas pressure as a mechanism of crater formation and, hence, should be continued on nuclear cratering events.

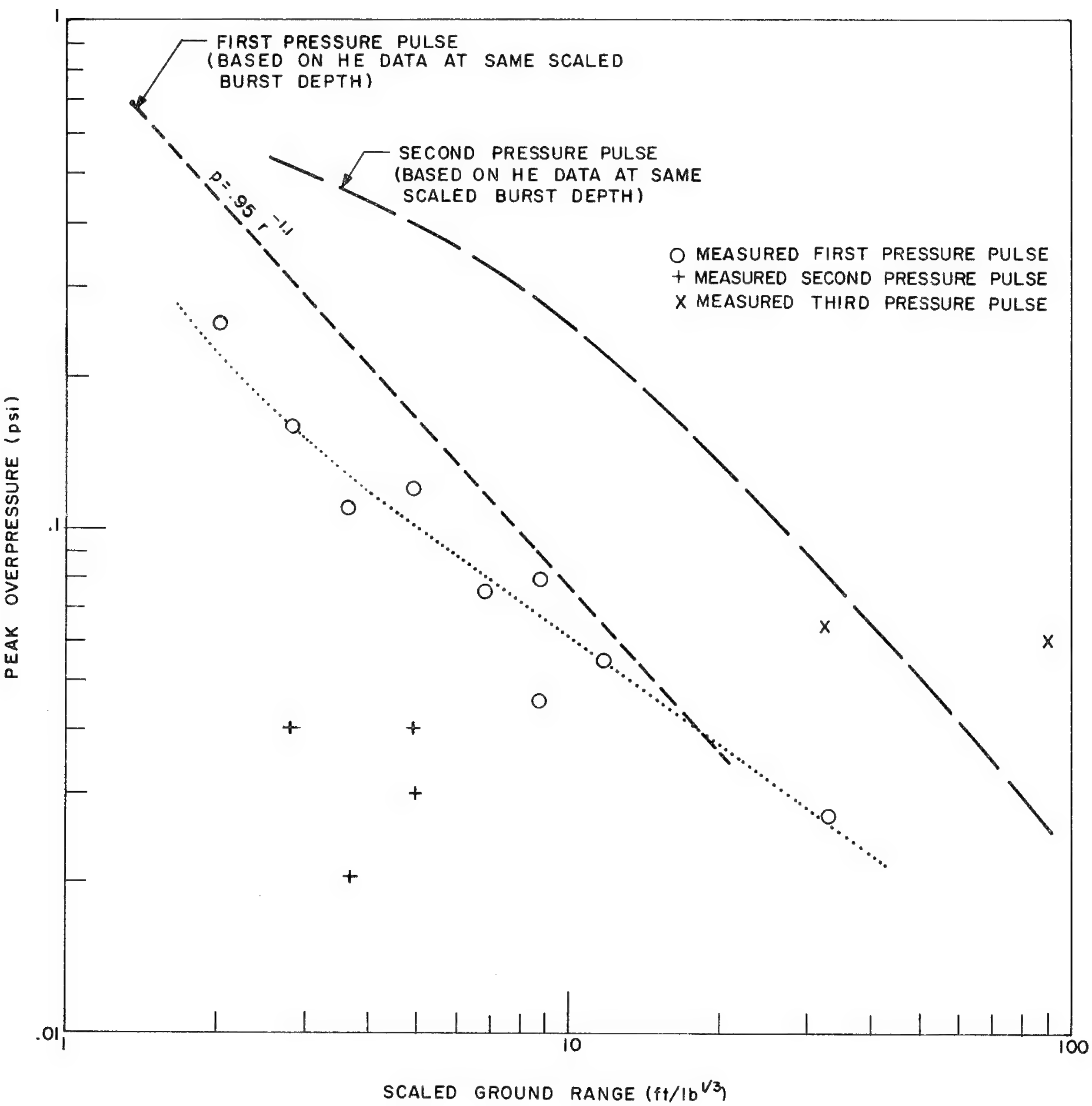


Figure 3.1 Maximum Overpressure versus Scaled Ground Range

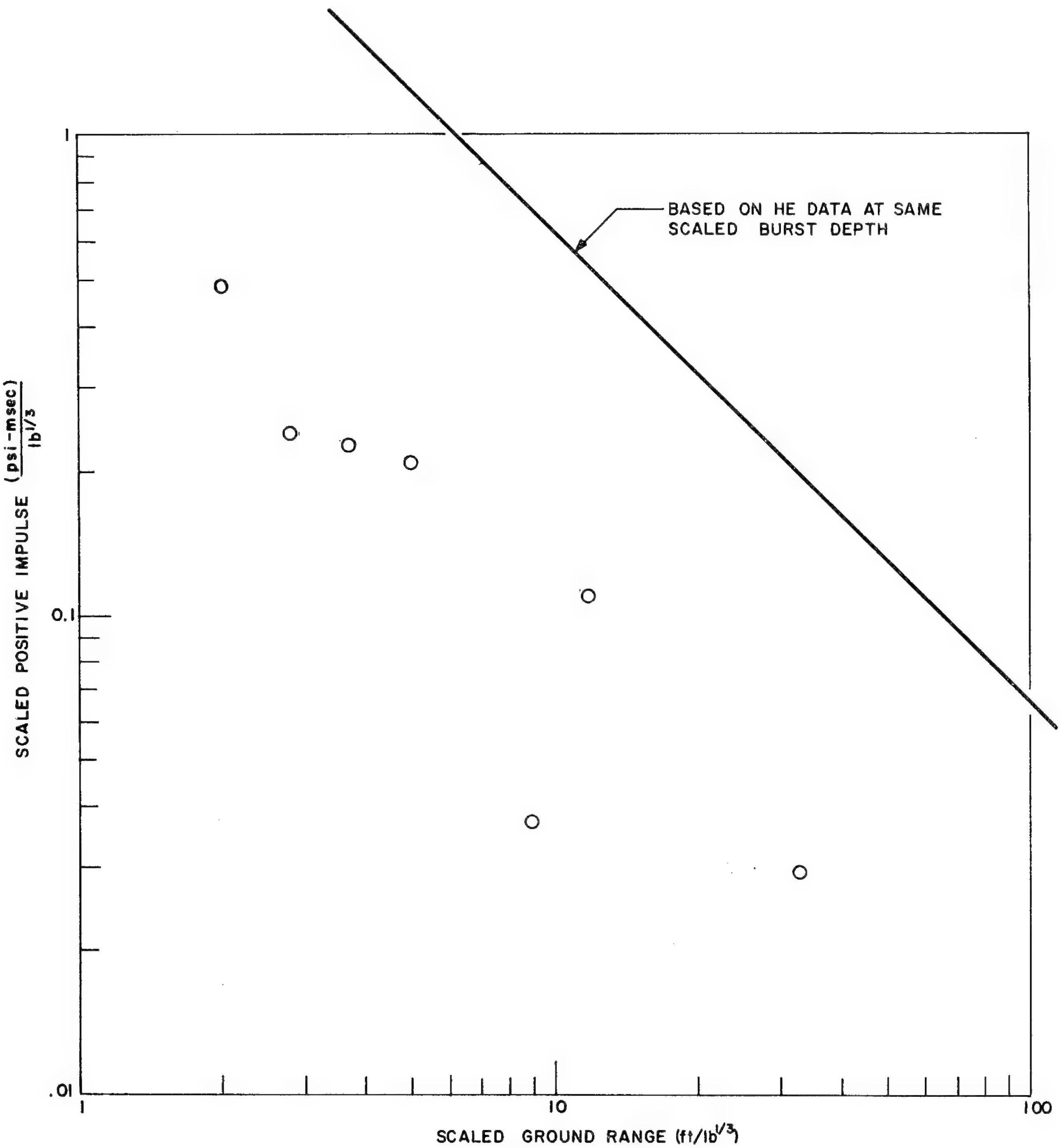


Figure 3.2 Scaled Positive Impulse versus Scaled Ground Range

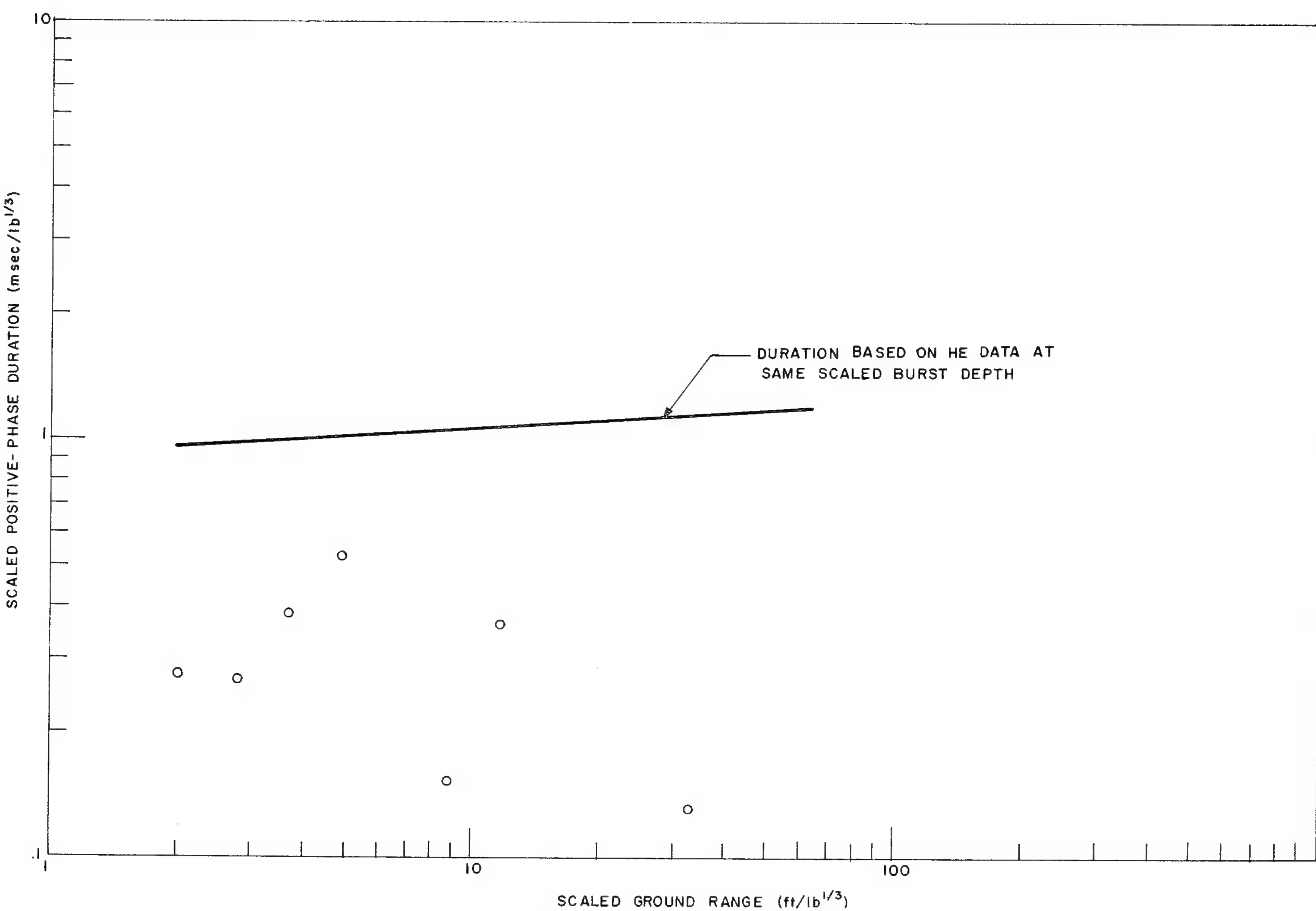


Figure 3.3 Scaled Positive Phase Duration versus Scaled Ground Range

CHAPTER 4

CONCLUSIONS

The dominant pressure pulse from the Danny Boy event is shown to have been the ground-shock-induced air blast. Only a very small pressure pulse resulting from the venting of explosive gases was recorded at the three closest stations. Since a significant pulse results from the venting gases of high-explosive detonations at the same scaled burst depths, this is the most pronounced difference between close-in air blast from nuclear and high-explosive detonations underground. Peak overpressures from venting gases were only about one-third those of the ground-shock-induced pulse, while with high explosives at the same scaled burst depths they were about three times the ground-shock-induced pressure. This drastic reduction in venting-gas pressures accounts almost entirely for the fact that the close-in blast from nuclear charges is suppressed more by charge burial than that from high-explosive charges.

The peak ground-shock-induced air pressure is shown to attenuate less rapidly for a nuclear charge in basalt than for high-explosive charges in the same medium.

The TNT equivalent of the blast from Project Danny Boy can be deduced only from the peak overpressures of the ground-shock-induced wave. Since the waves are attenuating at different rates, the apparent blast yield ranges from 75 tons at the closer stations to about 325 tons near the station at 1120 feet.

REFERENCES

1. Doll, E. B., and Salmon, V., Scaled HE Tests, Operation Jangle, WT-377, Project 1(9)-1, Stanford Research Institute, April 1952.

2. Sachs, D. C., and Swift, L. M., Small Explosion Tests, Project Mole, Vols. I and II, AFSWP-29-1, Stanford Research Institute, December 1955.

3. Murphey, B. F., and Ames, E. S., Air Pressure versus Depth of Burst, SCTM 42-59(51), Sandia Corporation, February 20, 1959.

4. Vortman, L. J., et al., Project Stagecoach, Final Report, SC-4596(RR), Sandia Corporation, January 1962.

5. Perret, W. R., Vortman, L. J., Chabai, A. J., and Reed, J. W., Mechanisms of Crater Formation, Project Scooter, Sandia Corporation, SC-4602(RR), to be published.

6. Eberhard, R. D., Kingery, C. N., and Molesky, W. F., Peak Air Blast Pressures from Shock Velocity Measurements Along the Ground, Operation Jangle, WT-323, Ballistic Research Laboratories, July 1952.

7. Howard, W. J., and Jones, R. D., Free Air Pressure Measurements, Operation Jangle, WT-306, Project 1.21, Sandia Corporation, February 19, 1952.

8. Sachs, D. C., and Swift, L. M., Underground Explosion Effects, WT-1106, Stanford Research Institute, March 23, 1958.

9. Vortman, L. J., et al., Project Buckboard, 20-ton and 1/2-ton Cratering Experiments in Basalt Rock, Final Report, Sandia Corporation, SC-4675(RR), to be published.

TECHNICAL REPORTS SCHEDULED FOR ISSUANCE

BY AGENCIES PARTICIPATING IN PROJECT DANNY BOY

AGENCY	PROJECT NO.	REPORT NO.	SUBJECT OR TITLE
SC	1.1a*	1809	Long-Range Air Blast Measurements and Interpretations
SC	1.1b*	1810	Close-In Air Blast from a Nuclear Detonation in Basalt
WES	1.2**	1811	Earth Motion Measurements
EG&G	1.3**	1812	Surface Phenomena Photography
USC&GS	1.4/26.3/8.1**	1813	Seismic Effects from a Nuclear Cratering Experiment in Basalt
ARF	1.5**	1814	Throwout Study of an Underground Nuclear Detonation
WES	1.6**	1815	Mass Distribution Studies of Ejecta and Dust
LRL	1.9/26.2**	1816	Crater Studies
LRL	21.1***	1817	Distribution of Radioactivity from a Nuclear Cratering Experiment
UCLA	2.4***	1818	Some Radiological Observations and Characteristics of Fallout Debris from a Nuclear Cratering Experiment
NDL	2.5***	1819	On-Site Fallout from a Partially Contained Nuclear Burst in a Hard Medium
LRL	26.1**	1820	Close-In Shock Studies
SC	26.4**	1821	Results of the Sandia Seismic Net
ERDL	7.3	1822	Vegetation Studies
SRI	7.5	1823	Visual and Photographic On-Site Inspection
Boeing	1.10**	1824	Permanent Angular Displacement of Cylindrical Models

AGENCY	PROJECT NO.	REPORT NO.	SUBJECT OR TITLE
EG&G	**	1825	Timing and Firing
WES	**	1826	Design, Testing, and Field Pumping of Grout Mixtures
LRL	**	1827	Effects on Magnetic Properties of Basalt and Magnetite-Bearing Grout
USGS	**	1828	Geology of U18a Site, Buckboard Mesa, Nevada Test Site, Nye County, Nevada
USGS	**	1829	Geologic Effects of Explosions on Basalt of Buckboard Mesa, Nevada Test Site, Nye County, Nevada
USPHS	***	1830	Off-Site Radiological Safety
USWB	***	1831	Report of Weather and Radiation Transport
REECo	***	1832	On-Site Radiological Safety
LRL		1833	Summary Report of a Nuclear Cratering Experiment

Notes: Reports marked with one asterisk are to receive a basic distribution of Military Category 12, those with two asterisks Military Category 14, and those with three asterisks Military Category 26.

ABBREVIATIONS FOR TECHNICAL AGENCIES

ARA	Allied Research Associates Inc. , Boston
ARF	Armour Research Foundation, Illinois Institute of Technology, Chicago 16
BOEING	The Boeing Company, Aero-Space Division, Seattle Attn: R. H. Carlson
EG&G	Edgerton, Germeshausen, and Grier, Inc. , Boston, Las Vegas, and Santa Barbara
ERDL	U. S. Army Engineer Research & Development Laboratory, Fort Belvoir
LRL	Lawrence Radiation Laboratory, Livermore
NDL	U. S. Army Chemical Corps., Nuclear Defense Laboratory, Maryland
REECo	Reynolds Electrical and Engineering Co. , Las Vegas
SC	Sandia Corporation, Albuquerque
SRI	Stanford Research Institute, Menlo Park
UCLA	University of California, Los Angeles
USC&GS	Coast and Geodetic Survey, Washington, D. C. and Las Vegas
USPHS	U. S. Public Health Service, Las Vegas
USWB	U. S. Weather Bureau, Las Vegas
WES	USA C of E Waterways Experiment Station, Vicksburg

DISTRIBUTION

Military Distribution Category 12

ARMY ACTIVITIES

1 Deputy Chief of Staff for Military Operations, D/A, Washington 25, D.C. ATTN: Dir. of SW&R
2 Chief of Research and Development, D/A, Washington 25, D.C. ATTN: Atomic Div.
3 Assistant Chief of Staff, Intelligence, D/A, Washington 25, D.C.
4 Chief of Engineers, D/A, Washington 25, D.C. ATTN: ENGNB
5 Chief of Engineers, D/A, Washington 25, D.C. ATTN: ENGEB
6 Chief of Engineers, D/A, Washington 25, D.C. ATTN: ENGTB
7- 8 Office, Chief of Ordnance, D/A, Washington 25, D.C. ATTN: ORDTN
9- 11 Commanding General, U.S. Continental Army Command, Ft. Monroe, Va.
12 Director of Special Weapons Development Office, Headquarters CONARC, Ft. Bliss, Tex. ATTN: Capt. Chester I. Peterson
13 President, U.S. Army Artillery Board, Ft. Sill, Okla.
14 President, U.S. Army Air Defense Board, Ft. Bliss, Tex.
15 Commandant, U.S. Army Command & General Staff College, Ft. Leavenworth, Kansas. ATTN: ARCHIVES
16 Commandant, U.S. Army Armored School, Ft. Knox, Ky.
17 Commandant, U.S. Army Artillery and Missile School, Ft. Sill, Okla. ATTN: Combat Development Department
18 Commandant, U.S. Army Aviation School, Ft. Rucker, Ala.
19 Commandant, U.S. Army Infantry School, Ft. Benning, Ga. ATTN: C.D.S.
20 Commandant, U.S. Army Ordnance and Guided Missile School, Redstone Arsenal, Ala.
21 Commanding General, Chemical Corps Training Comd., Ft. McClellan, Ala.
22 Commanding General, The Engineer Center, Ft. Belvoir, Va. ATTN: Asst. Cmdt, Engr. School
23 Director, Armed Forces Institute of Pathology, Walter Reed Army Med. Center, 625 16th St., NW, Washington 25, D.C.
24 Commanding Officer, Army Medical Research Lab., Ft. Knox, Ky.
25 Commandant, Walter Reed Army Inst. of Res., Walter Reed Army Medical Center, Washington 25, D.C.
26 Commanding General, Qm R&E Comd., QM R&E Cntr., Natick, Mass. ATTN: Tech. Library
27- 28 Commanding Officer, Chemical Warfare Lab., Army Chemical Center, Md. ATTN: Tech. Library
29 Commanding General, Engineer Research and Dev. Lab., Ft. Belvoir, Va. ATTN: Chief, Tech. Support Branch
30 Director, Waterways Experiment Station, P.O. Box 631, Vicksburg, Miss. ATTN: Library
31 Commanding Officer, Picatinny Arsenal, Dover, N.J. ATTN: ORDBB-TK
32 Commanding Officer, Diamond Ord. Fuze Labs., Washington 25, D.C. ATTN: Chief, Nuclear Vulnerability Br. (230)
33- 34 Commanding General, Aberdeen Proving Grounds, Md. ATTN: Director, Ballistics Research Laboratory
35 Commanding General, Frankford Arsenal, Bridge and Tacony St., Philadelphia, Pa.
36 Commanding Officer, Watervliet Arsenal, Watervliet, New York. ATTN: ORDBF-RR
37 Commander, Army Rocket and Guided Missile Agency, Redstone Arsenal, Ala. ATTN: Tech Library
38 Commanding General, White Sands Missile Range, N. Mex. ATTN: ORDBS-OM
39 Commander, Army Ballistic Missile Agency, Redstone Arsenal, Ala. ATTN: ORDAB-HT
40 Commanding General, Ordnance Tank Automotive Command, Detroit Arsenal, Centerline, Mich. ATTN: ORDMC-RO
41 Commanding General, Ordnance Weapons Command, Rock Island, Ill.
42 Commanding General, U.S. Army Electronic Proving Ground, Ft. Huachuca, Ariz. ATTN: Tech. Library
43 Commanding General, USA Combat Surveillance Agency, 1124 N. Highland St., Arlington, Va.
44 The Research Analysis Corp., 6935 Arlington Rd., Bethesda 14, Md.
45 Commanding General, U. S. ORD Special Weapons-Ammunition Command, Dover, N.J.

NAVY ACTIVITIES

46- 47 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-03EG
48 Chief of Naval Operations, D/N, Washington 25, D.C. ATTN: OP-75
49- 50 Chief of Naval Research, D/N, Washington 25, D.C. ATTN: Code 811
51- 53 Chief, Bureau of Naval Weapons, D/N, Washington 25, D.C. ATTN: DLI-3
54- 58 Chief, Bureau of Naval Weapons, D/N, Washington 25, D.C. ATTN: RAAD-25
59 Chief, Bureau of Ordnance, D/N, Washington 25, D.C.
60 Chief, Bureau of Ships, D/N, Washington 25, D.C. ATTN: Code 423
61 Chief, Bureau of Yards and Docks, D/N, Washington 25, D.C. ATTN: D-440
62 Director, U.S. Naval Research Laboratory, Washington 25, D.C. ATTN: Mrs. Katherine H. Cass
63- 64 Commander, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring 19, Md.
65 Director, Material Lab. (Code 900), New York Naval Shipyard, Brooklyn 1, N.Y.
66 Commanding Officer and Director, Navy Electronics Laboratory, San Diego 52, Calif.
67 Commanding Officer, U.S. Naval Mine Defense Lab., Panama City, Fla.
68- 69 Commanding Officer, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif. ATTN: Tech. Info. Div.
70- 71 Commanding Officer and Director, U.S. Naval Civil Engineering Laboratory, Port Hueneme, Calif. ATTN: Code L31
72 Commanding Officer, U.S. Naval Schools Command, U.S. Naval Station, Treasure Island, San Francisco, Calif.
73 Superintendent, U.S. Naval Postgraduate School, Monterey, Calif.
74 Commanding Officer, U.S. Fleet Sonar School, U.S. Naval Base, Key West, Fla.
75 Commanding Officer, U.S. Fleet Sonar School, San Diego 47, Calif.
76 Officer-in-Charge, U.S. Naval School, CEC Officers, U.S. Naval Construction Bn. Center, Port Hueneme, Calif.
77 Commanding Officer, Nuclear Weapons Training Center, Atlantic, U.S. Naval Base, Norfolk 11, Va. ATTN: Nuclear Warfare Dept.
78 Commanding Officer, Nuclear Weapons Training Center, Pacific, Naval Station, San Diego, Calif.
79 Commanding Officer, U.S. Naval Damage Control Tng. Center, Naval Base, Philadelphia 12, Pa. ATTN: ABC Defense Course
80 Commanding Officer, Air Development Squadron 5, VX-5, China Lake, Calif.

81 Commanding Officer, Naval Air Material Center, Philadelphia 12, Pa. ATTN: Technical Data Br.
82 Commanding Officer U.S. Naval Air Development Center, Johnsville, Pa. ATTN: NAS, Librarian
83 Commanding Officer, U.S. Naval Medical Research Institute, National Naval Medical Center, Bethesda, Md.
84- 85 Commanding Officer and Director, David W. Taylor Model Basin, Washington 7, D.C. ATTN: Library
86 Commanding Officer and Director, U.S. Naval Engineering Experiment Station, Annapolis, Md.
87 Commander, Norfolk Naval Shipyard, Portsmouth, Va. ATTN: Underwater Explosions Research Division
88 Commandant, U.S. Marine Corps, Washington 25, D.C. ATTN: Code AO3H
89 Director, Marine Corps Landing Force, Development Center, MCS, Quantico, Va.
90- 98 Chief, Bureau of Naval Weapons, Navy Department, Washington 25, D.C. ATTN: RR12
99 Commander-in-Chief, U.S. Pacific Fleet, Fleet Post Office, San Francisco, Calif.
100 Commanding General, Fleet Marine Force, Pacific, Fleet Post Office, San Francisco, Calif.

AIR FORCE ACTIVITIES

101 Air Force Technical Application Center, HQ. USAF, Washington 25, D. C.
102 Hq. USAF, ATTN: Operations Analysis Office, Office, Vice Chief of Staff, Washington 25, D. C.
103 Director of Civil Engineering, HQ. USAF, Washington 25, D.C. ATTN: AFOCE-ES
104-108 HQ. USAF, Washington 25, D.C. ATTN: AFCIN-3D1
109 Director of Research and Development, DCS/D, HQ. USAF, Washington 25, D.C. ATTN: Guidance and Weapons Div.
110 The Surgeon General, HQ. USAF, Washington 25, D.C. ATTN: Bio.-Def. Pre. Med. Division
111 Commander, Tactical Air Command, Langley AFB, Va. ATTN: Doc. Security Branch
112 Commander, Air Defense Command, Ent AFB, Colorado. ATTN: Operations Analysis Section, ADOOA
113 Commander, Hq. Air Research and Development Command, Andrews AFB, Washington 25, D.C. ATTN: RDRWA
114 Commander, Air Force Ballistic Missile Div. HQ. ARDC, Air Force Unit Post Office, Los Angeles 45, Calif. ATTN: WDSOT
115 Commander, Second Air Force, Barksdale AFB, La. ATTN: Operations Analysis Office
116-117 Commander, AF Cambridge Research Center, L. G. Hanscom Field, Bedford, Mass. ATTN: CRQST-2
118-122 Commander, Air Force Special Weapons Center, Kirtland AFB, Albuquerque, N. Mex. ATTN: Tech. Info. & Intel. Div.
123-124 Director, Air University Library, Maxwell AFB, Ala.
125 Commander, Lowry Technical Training Center (TW), Lowry AFB, Denver, Colorado.
126 Commandant, School of Aviation Medicine, USAF Aerospace Medical Center (ATC), Brooks AFB, Tex. ATTN: Col. G. L. Hekhuis
127-129 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, Ohio. ATTN: WCACT (For WCOSI)
130-131 Director, USAF Project RAND, VIA: USAF Liaison Office, The RAND Corp., 1700 Main St., Santa Monica, Calif.
132 Commander, Rome Air Development Center, ARDC, Griffiss AFB, N.Y. ATTN: Documents Library, RCSSL-1
133 Commander, Air Technical Intelligence Center, USAF, Wright-Patterson AFB, Ohio. ATTN: AFCIN-4B1a, Library
134 Assistant Chief of Staff, Intelligence, HQ. USAFE, APO 633, New York, N. Y. ATTN: Directorate of Air Targets
135 Commander-in-Chief, Pacific Air Forces, APO 953, San Francisco, Calif. ATTN: PFCIE-MB, Base Recovery

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

136 Director of Defense Research and Engineering, Washington 25, D.C. ATTN: Tech. Library
137 Chairman, Armed Services Explosives Safety Board, DOD, Building T-7, Gravelly Point, Washington 25, D.C.
138 Director, Weapons Systems Evaluation Group, Room 1E880, The Pentagon, Washington 25, D.C.
139-142 Chief, Defense Atomic Support Agency, Washington 25, D.C. ATTN: Document Library
143 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex.
144 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex. ATTN: FCTG
145-146 Commander, Field Command, DASA, Sandia Base, Albuquerque, N. Mex. ATTN: FCWT
147 Administrator, National Aeronautics and Space Administration, 1520 "H" St., N.W., Washington 25, D.C. ATTN: Mr. R. V. Rhode
148 Commander-in-Chief, Strategic Air Command, Offutt AFB, Neb. ATTN: OAWS
149 U.S. Documents Officer, Office of the United States National Military Representative - SHAPE, APO 55, New York, N.Y.

ATOMIC ENERGY COMMISSION ACTIVITIES

150-152 U.S. Atomic Energy Commission, Technical Library, Washington 25, D.C. ATTN: For DMA
153-154 Los Alamos Scientific Laboratory, Report Library, P.O. Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman
155-159 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: H. J. Smyth, Jr.

SUPPLEMENTARY DISTRIBUTION

160 Assistant to the Secretary of Defense for Atomic Energy, Department of Defense, Washington 25, D.C. ATTN: Dr. Gerald W. Johnson
161-166 Chief, Advanced Research Projects Agency, Washington 25, D.C.
167-172 Chief, Defense Atomic Support Agency, Washington 25, D.C.
173-178 Chief, Air Force Technical Applications Center, Washington 25, D.C.
179-193 Commander, Field Command, Defense Atomic Support Agency, Sandia Base, Albuquerque, N. Mex. ATTN: FCWT
194-198 Headquarters, DOD Test Organization, Field Command, DASA, P. O. Box 207, Mercury, Nev.
199 Commander, Air Force Cambridge Research Lab., Laurence G. Hanscom Field, Bedford, Mass.
200-201 Holmes & Narver, Inc., 849 South Broadway, Los Angeles 14, Calif. ATTN: Project Officer, Proj. 3.1
202-203 Applied Physics Research Laboratory, College Park, Md. ATTN: Project Officer, Proj. 3.6
204-205 Edgerton, Germeshausen & Grier, Inc., 300 Wall Street, Las Vegas, Nev. ATTN: Project Officer, Proj. 1.3
206-207 United ElectroDynamics, Inc., 200 Allendale Road, Pasadena, Calif.
208-209 Director, Waterways Experiment Station, Jackson, Miss. ATTN: Project Officer, Proj. 9.1
210-211 Los Alamos Scientific Laboratory, P. O. Box 1663, Los Alamos, N. Mex.
212-213 U. S. Atomic Energy Commission, Albuquerque Operations Office, P. O. Box 5400, Albuquerque, N. Mex. ATTN: K. F. Hertford
214-233 U. S. Atomic Energy Commission, Nevada Operations Office, P. O. Box 1676, Las Vegas, Nev. ATTN: Document Custodian
234 Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio. ATTN: Dr. H. W. Russell
235 Director, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.
236-237 University of California, Lawrence Radiation Laboratory, Technical Information Division, Berkeley 4, Calif. ATTN: Dr. R. K. Wakerling
238-272 University of California, Lawrence Radiation Laboratory, Technical Information Division, P. O. Box 808, Livermore, Calif. ATTN: C. G. Craig
273-276 Union Carbide Nuclear Company, X-10 Laboratory Records Department, P. O. Box X, Oak Ridge, Tenn.
277 Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Ill. ATTN: Dr. Hoylande D. Young
278 University of California, Lawrence Radiation Laboratory, Technical Information Div., P. O. Box 808, Livermore, Calif. ATTN: Clovis Craig (For Test Group Div., Mercury, Nev.)

279 Los Alamos Scientific Laboratory, P. O. Box 1663, Los Alamos, N. Mex. ATTN: Report Librarian
280 Los Alamos Scientific Laboratory, P. O. Box 1663, Los Alamos, N. Mex. ATTN: Report Librarian (For Test Group Div., Mercury, Nev.)
281-282 Sandia Corp., P. O. Box 5800, Albuquerque, N. Mex. ATTN: Records Management and Services Dept. (For Project Officer, Proj. 3.3)
283-284 Director, Stanford Research Institute, Menlo Park, Calif. ATTN: Document Custodian
285-286 Space Technology Laboratories, Inc., One Space Park, Redondo Beach, Calif. ATTN: Project Officer, Proj. 3.12
287 U. S. Atomic Energy Commission, San Francisco Operations Office, 2111 Bancroft Way, Berkeley 4, Calif. ATTN: Tech. Serv. Div.
288 U. S. Geological Survey, Washington 25, D. C. ATTN: Dr. Thomas B. Nolan
289 U. S. Geological Survey, Tepco Building 25, Federal Center, Denver 25, Colo. ATTN: F. W. Stead
290 U. S. Public Health Service, Division of Radiological Health, Rm. 5094 South Building, 4th and C Streets, S.W., Washington 25, D. C. ATTN: James G. Terrill, Jr.
291 Brookhaven National Laboratory, Technical Information Division, Upton, Long Island, N. Y. ATTN: Classified Doc. Group
292-293 U. S. Army Chemical Corps, Nuclear Defense Laboratory, U. S. Army Proving Ground, Md.
294-295 University of Michigan, Central Document Control Station, Rm. 2202, Administrative Office, Ann Arbor, Mich. ATTN: VESIAC
296-299 Sandia Corp., Sandia Base, P. O. Box 5800, Albuquerque, N. Mex. ATTN: Records Management and Services Dept.
300 Sandia Corp., Livermore Branch, Livermore, Calif. ATTN: Document Control Section
301 U. S. Bureau of Mines, Washington 25, D. C. ATTN: John E. Crawford, Chief Nuclear Engineer
302-304 Laboratory of Nuclear Medicine and Radiation Biology, School of Medicine, Univ. of California, Los Angeles, 900 Veteran Ave., Los Angeles 24, Calif. ATTN: Harland B. Thompson
305-306 Armour Research Foundation, 10 W. 35th St., Chicago 16, Ill. ATTN: Document Library
307-311 U. S. Atomic Energy Commission, Technical Library, Washington 25, D. C. (For DPNE)
312-316 U. S. Atomic Energy Commission, Technical Library, Washington 25, D. C.
317 U. S. Army Engineer Research and Development Laboratory, Ft. Belvoir, Va. ATTN: S. E. Dwornik
318 U. S. Coast and Geodetic Survey, Seismological Field Survey, 133 Herman St., San Francisco, Calif. ATTN: William K. Cloud
319-321 Director, U. S. Coast and Geodetic Survey, U. S. Dept. of Commerce, Washington 25, D. C. ATTN: Dr. Dean Carder
322 U. S. Atomic Energy Commission, Nevada Operations Office, P. O. Box 1676, Las Vegas, Nev. ATTN: Thomas Pierce, U. S. Coast and Geodetic Survey
323 U. S. Atomic Energy Commission, Division of Technical Information Extension, Oak Ridge, Tenn. (Master)
324-405 U. S. Atomic Energy Commission, Division of Technical Information Extension, Oak Ridge, Tenn. (Surplus)